Tracheostomy Tubes and Related Appliances

Dean R Hess PhD RRT FAARC

Tracheostomy tubes are used to administer positive-pressure ventilation, to provide a patent airway, to provide protection from aspiration, and to provide access to the lower respiratory tract for airway clearance. They are available in a variety of sizes and styles, from several manufacturers. The dimensions of tracheostomy tubes are given by their inner diameter, outer diameter, length, and curvature. Differences in length between tubes of the same inner diameter, but from different manufacturers, are not commonly appreciated but may have important clinical implications. Tracheostomy tubes can be angled or curved, a feature that can be used to improve the fit of the tube in the trachea. Extra proximal length tubes facilitate placement in patients with large necks, and extra distal length tubes facilitate placement in patients with tracheal anomalies. Several tube designs have a spiral wire reinforced flexible design and have an adjustable flange design to allow bedside adjustments to meet extra-length tracheostomy tube needs. Tracheostomy tubes can be cuffed or uncuffed. Cuffs on tracheostomy tubes include high-volume low-pressure cuffs, tight-to-shaft cuffs, and foam cuffs. The fenestrated tracheostomy tube has an opening in the posterior portion of the tube, above the cuff, which allows the patient to breathe through the upper airway when the inner cannula is removed. Tracheostomy tubes with an inner cannula are called dual-cannula tracheostomy tubes. Several tracheostomy tubes are designed specifically for use with the percutaneous tracheostomy procedure. Others are designed with a port above the cuff that allows for subglottic aspiration of secretions. The tracheostomy button is used for stoma maintenance. It is important for clinicians caring for patients with a tracheostomy tube to understand the nuances of various tracheostomy tube designs and to select a tube that appropriately fits the patient. *Key words: airway management, fenestration, inner cannula, tracheostomy button, tracheostomy tube, cuff, tracheostomy, suction, stoma*. [Respir Care 2005;50(4):497–510. © 2005 Daedalus Enterprises]

Dean R Hess PhD RRT FAARC is affiliated with the Department of Respiratory Care, Massachusetts General Hospital, and Harvard Medical School, Boston, Massachusetts.

Dean R Hess PhD RRT FAARC presented a version of this paper at the 20th Annual New Horizons Symposium at the 50th International Respiratory Congress, held December 4–7, 2004, in New Orleans, Louisiana.

Correspondence: Dean R Hess PhD RRT FAARC, Respiratory Care, Ellison 401, Massachusetts General Hospital, 55 Fruit Street, Boston MA 02114. E-mail: dhess@partners.org.

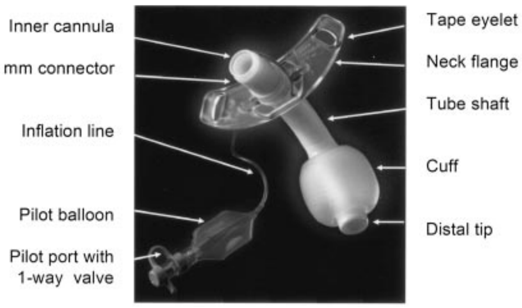


Fig. 1. Components of a standard tracheostomy tube. (Courtesy of Smiths Medical, Keene, New Hampshire.)

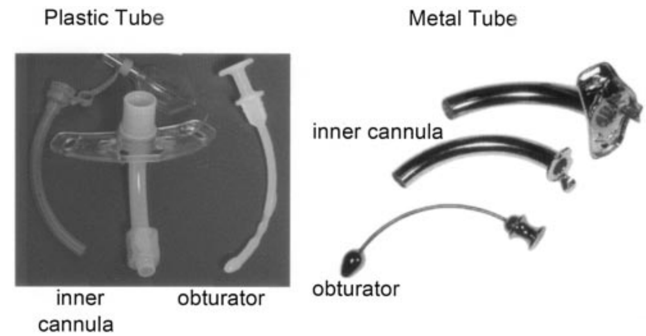


Fig. 2. Tracheostomy tube with inner cannula and obturator.

Introduction

Tracheostomy tubes are used to administer positive-pressure ventilation, to provide a patent airway in patients prone to upper-airway obstruction, to protect against aspiration, and to provide access to the lower respiratory tract for airway clearance. Tracheostomy tubes are available in a variety of sizes and styles from several manufacturers. The inner diameter (ID), outer diameter (OD), and any other distinguishing characteristics (percutaneous, extra length, fenestrated) are marked on the flange of the tube as a guide to the clinician. Some features are relatively standard among typical tracheostomy tubes (Fig. 1). However, there are many nuances among them. It is important for clinicians caring for patients with a tracheostomy tube to understand these differences and to use that understanding to select a tube that appropriately fits the patient. Surprisingly little has been published in the peer-reviewed literature on the topic of tracheostomy tubes and related appliances.[1–3] This paper describes characteristics of tracheostomy tubes used in adult patients.

Metal Versus Plastic Tracheostomy Tubes

Tracheostomy tubes can be metal or plastic (Fig. 2). Metal tubes are constructed of silver or stainless steel. Metal tubes are not used commonly because of their expense, their rigid construction, the lack of a cuff, and the lack of a 15-mm connector to attach a ventilator. A smooth rounded-tip obturator passed through the lumen of the tracheostomy tube facilitates insertion of the tube. The obturator is removed once the tube is in place. Plastic tubes are most commonly used and can be made from polyvinyl chloride or silicone. Polyvinyl chloride softens at body temperature (thermolabile), conforming to patient anatomy and centering the distal tip in the trachea. Silicone is naturally soft and unaffected by temperature. Some plastic tracheostomy tubes are packaged with a tracheal wedge (Fig. 3). The tracheal wedge facilitates removal of the ventilator circuit while minimizing the risk of dislodgement of the tracheostomy tube.

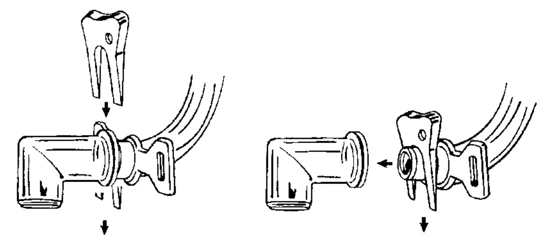


Fig. 3. The tracheal wedge is used to disconnect the ventilator circuit while minimizing the risk of dislodgement of the tracheostomy tube. (Courtesy of Smiths Medical, Keene, New Hampshire.)

Tracheostomy Tube Dimensions

The dimensions of tracheostomy tubes are given by their ID, OD, length, and curvature. The sizes of some tubes are given by Jackson size, which was developed for metal tubes and refers to the length and taper of the OD. These tubes have a gradual taper from the proximal to the distal tip. The Jackson sizing system is still used for most Shiley dual-cannula tracheostomy tubes (Table 1). Single-cannula tracheostomy tubes use the International Standards Organization method of sizing, determined by the ID of the outer cannula at its smallest dimension. Dual-cannula tracheostomy tubes with one or more shaft sections that are straight (eg, angled tubes) also use the International Standards Organization method. The ID of the tube is the functional ID. If an inner cannula is required for connection to the ventilator, the published ID is the ID of the inner cannula. The OD is the largest diameter of the outer cannula.

When selecting a tracheostomy tube, the ID and OD must be considered. If the ID is too small, it will increase the resistance through the tube, make airway clearance more difficult, and increase the cuff pressure required to create a seal in the trachea. Mullins et al[4] estimated the

Table 1. Jackson Tracheostomy Tube Size

Jackson Size	Inner Diameter With IC (mm)	Inner Diameter Without IC (mm)*	Outer Diameter (mm)
4	5.0	6.7	9.4
6	6.4	8.1	10.8
8	7.6	9.1	12.2
10	8.9	10.7	13.8

*The inner diameter of the outer cannula is for narrowest portion of the shaft.
IC = inner cannula (Adapted from Shiley Quick Reference Guide, courtesy of Tyco Healthcare, Pleasanton, California.)

Table 2. Dimensions of Portex Flex DIC and Shiley SCT Tracheostomy Tubes*

Portex Flex DIC			Shiley SCT		
ID (mm)	OD (mm)	Length (mm)	ID (mm)	OD (mm)	Length (mm)
6.0	8.2	64	6.0	8.3	67
7.0	9.6	70	7.0	9.6	80
8.0	10.9	74	8.0	10.9	89
9.0	12.3	80	9.0	12.1	99
10.0	13.7	80	10.0	13.3	105

*Note that the principal difference between the tubes is in their length. The Portex tube can be used with an inner cannula, which reduces the inner diameter (ID) by 1 mm.
DIC = disposable inner cannula
SCT = single cannula tube.
OD = outer diameter

resistance through Shiley tracheostomy tubes at 11.47, 3.96, 1.75, and 0.69 cm H_2O/L/s for size 4, 6, 8, and 10 adult tubes, respectively. If the OD is too large, leak with the cuff deflated will be decreased, and this will affect the ability to use the upper airway with cuff deflation (eg, speech). A tube with a larger OD will also be more difficult to pass through the stoma. A 10-mm OD tube is usually appropriate for adult women, and an 11-mm OD tube is usually appropriate for adult men as an initial tracheostomy tube size. Differences in tracheostomy tube length between tubes of the same ID but from different manufacturers are not commonly appreciated (Table 2), and this can have important clinical implications (Fig. 4).

Tracheostomy tubes can be angled or curved (Fig. 5), a feature that can be used to improve the fit of the tube in the trachea. The shape of the tube should conform as closely as possible to the anatomy of the airway. Because the trachea is essentially straight, the curved tube may not conform to the shape of the trachea, potentially allowing for compression of the membranous part of the trachea, while the tip may traumatize the anterior portion. If the curved tube is too short, it can obstruct against the posterior tracheal wall (Fig. 6), which can be remedied by using either a larger tube, an angled tube, a tube with a flexible shaft, or a tube with extra length. Angled tracheostomy tubes have a curved portion and a straight portion. They enter the trachea at a less acute angle and may cause less pressure at the stoma. Because the portion of the tube that extends into the trachea is straight and conforms more closely to the natural anatomy of the airway, the angled tube may be better centered in the trachea and cause less pressure along the tracheal wall.

Tracheostomy tubes are available in standard length or extra length. Extra-length tubes are constructed with extra proximal length (horizontal extra length) or with extra distal length (vertical extra length) (Fig. 7). In the case of one manufacturer, extra distal length is achieved by a double cuff design (Fig. 8 and Table 3). This design also allows the cuffs to be alternatively inflated and deflated, which may reduce the risk of tracheal-wall injury, although this has never been subjected to appropriate clinical study. Extra proximal length facilitates tracheostomy tube placement in patients with a large neck (eg, obese patients). Extra distal length facilitates placement in patients with tracheal malacia or tracheal anomalies. Care must be taken to avoid inappropriate use of these tubes, which may induce distal obstruction of the tube. Rumbak et al[5] reported a series of 37 patients in whom substantial tracheal obstruction (tracheal malacia, tracheal stenosis, or granulation tissue formation) caused failure to wean from mechanical ventilation. In 34 of the 37 patients, the obstruction was relieved by use of a longer tube, which effectively bypassed the tracheal obstruction.

Several tube designs have a spiral wire reinforced flexible design (Fig. 9 and Table 4). These also have an adjustable flange design to allow bedside adjustments to meet extra-length tracheostomy tube needs. These tubes are not compatible with lasers, electrosurgical devices, or magnetic resonance imaging. Because the locking mechanism on the flange tends to deteriorate over time, use of these tubes should be considered a temporary solution. For long-term use, the adjustable-flange tube should be replaced with a tube that has a fixed flange. Custom-constructed tubes are available from several manufacturers to meet this need.

Low-profile tracheostomy tubes (Fig. 10) can be used in patients with laryngectomy or sleep apnea. They have a small discreet flange, and they can be cuffed or uncuffed. One of 2 inner cannulae can be used. A low-profile inner cannula is used for spontaneous breathing, and an inner cannula with a 15-mm connector can be used to attach a ventilator.

Tracheostomy Tube Cuffs

Tracheostomy tubes can be cuffed or uncuffed (Fig. 11). Uncuffed tubes allow airway clearance but provide no

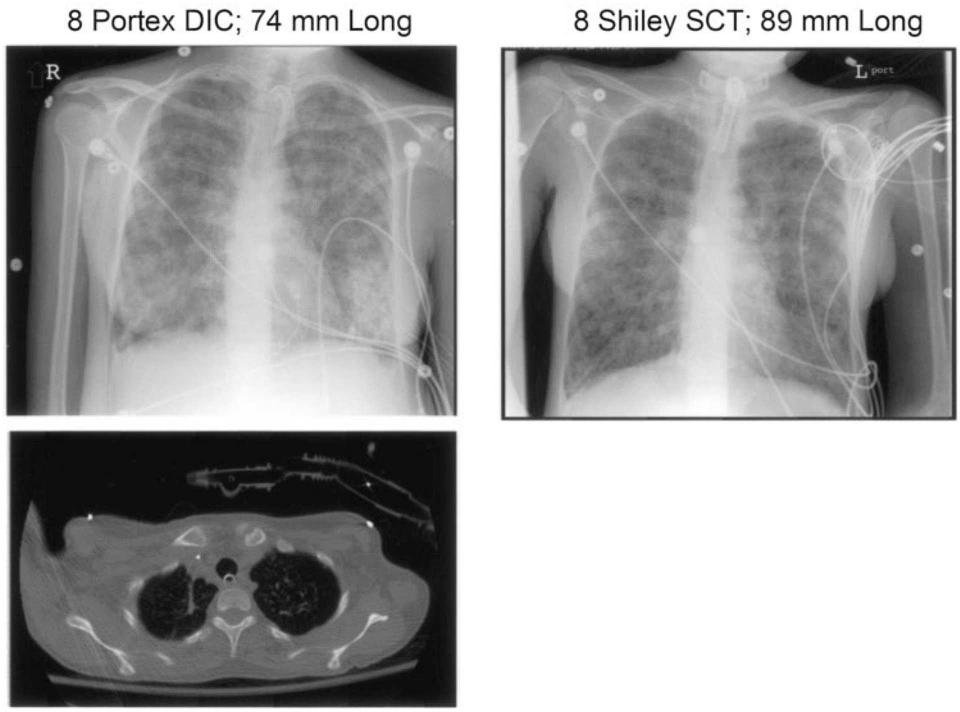


Fig. 4. A patient with a Portex 8 tracheostomy tube in place. Note the poor fit on both the anterior-posterior film and the transverse section by computed tomography (left). Note the improved fit when the tube was changed to a Shiley 8 single-cannula tube (SCT). The principal difference between the tubes is their length. DIC = disposable inner cannula.

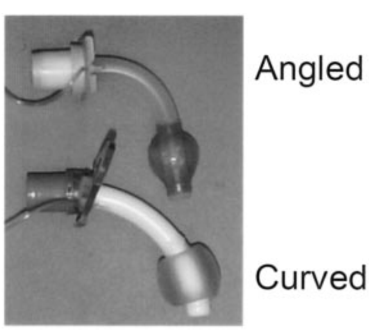


Fig. 5. Angled versus curved tracheostomy tubes. Note that the angled tube has a straight portion and a curved portion, whereas the curved tube has a uniform angle of curvature.

protection from aspiration. Cuffed tracheostomy tubes allow for airway clearance, offer some protection from aspiration, and positive-pressure ventilation can be more effectively applied when the cuff is inflated. Although cuffed tubes are generally considered necessary to provide effective positive-pressure ventilation, a cuffless tube can be used effectively in long-term mechanically ventilated patients with adequate pulmonary compliance and sufficient oropharyngeal muscle strength for functional swallowing and articulation.[6] Specific types of cuffs used on tracheostomy tubes include high-volume low-pressure cuffs, tight-to-shaft cuffs (low-volume high-pressure), and foam cuffs (Fig. 12). High-volume low-pressure cuffs are most commonly used.

Tracheal capillary perfusion pressure is normally 25–35 mm Hg. High tracheal-wall pressures exerted by the inflated cuff can produce tracheal mucosal injury (Fig. 13).[7–15] Because the pressure transmitted from the cuff to tracheal wall is usually less than the pressure in the cuff, it is generally agreed that 25 mm Hg (34 cm H_2O) is the maximum acceptable intra-cuff pressure. If the cuff pressure is too low, silent aspiration is more likely.[16,17] Therefore, it is recommended that cuff pressure be maintained at 20–25 mm Hg (25–35 cm H_2O) to minimize the risks for both tracheal-wall injury and aspiration. A leak around the cuff is assessed by auscultation over the suprasternal notch or the lateral neck. Techniques such as the minimum occlusion pressure or the minimum leak technique are not recommended. In particular, the minimum leak technique is not recommended because of the risk of silent aspiration of pharyngeal secretions.

Intra-cuff pressure should be monitored and recorded regularly (eg, once per shift) and more often if the tube is changed, if its position changes, if the volume of air in the cuff is changed, or if a leak occurs. Cuff pressure is measured with a syringe, stopcock, and manometer (Fig. 14). This method allows cuff pressure to be measured simultaneously with adjustment of cuff volume. Methods in which the manometer is attached directly to the pilot bal-

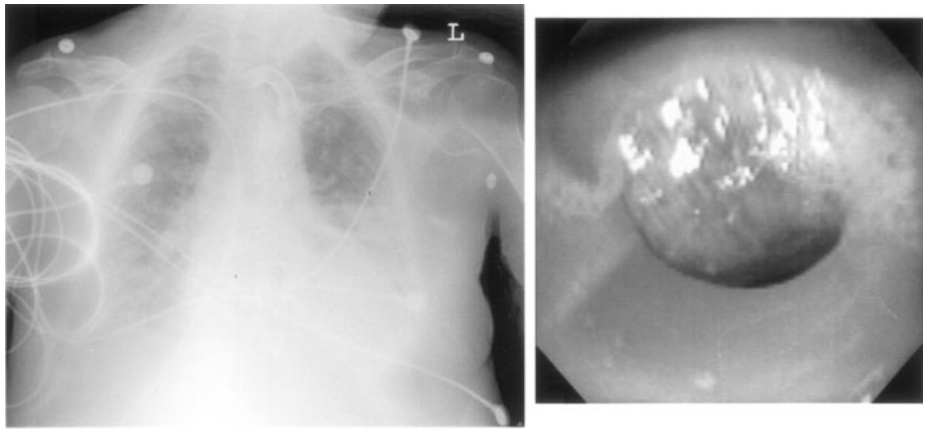


Fig. 6. A curved tracheostomy tube in which the distal end abuts the posterior tracheal wall. There is a hint of this on the anterior-posterior chest radiograph (left), and this was confirmed by bronchoscopy (right). Approaches to this problem include replacing the tube with one that is larger, angled, or of extra length.

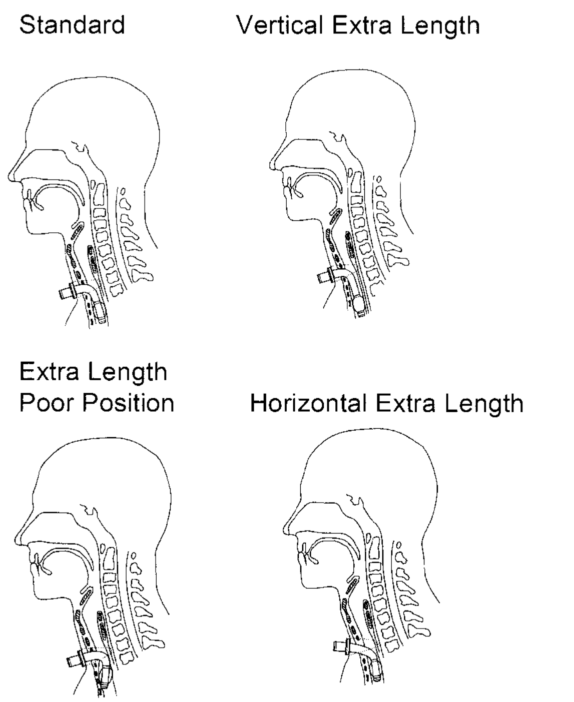


Fig. 7. Position of extra-length tracheostomy tubes in the trachea. Note that inappropriate use of an extra-length tube can cause distal tracheostomy-tube obstruction. (From Reference 5, with permission.)

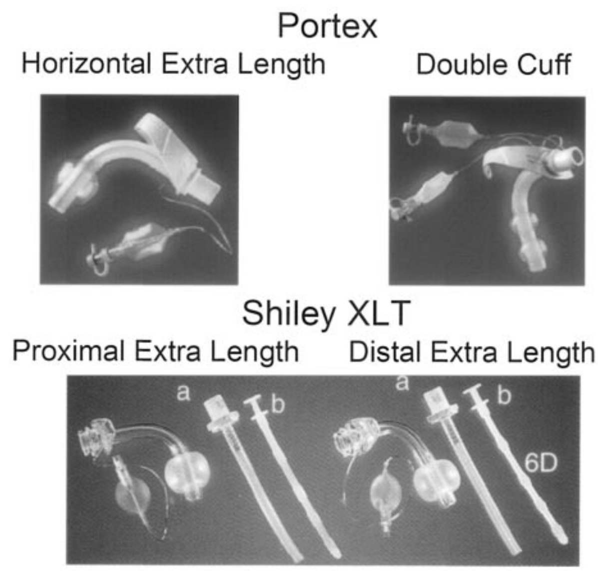


Fig. 8. Extra-length tracheostomy tubes. (Courtesy of Smiths Medical, Keene, New Hampshire and Tyco Healthcare, Pleasanton, California.)

loon are discouraged because they cause air to escape from the cuff to pressurize the manometer. Commercially available systems can also be used to measure cuff pressure.

A common cause of high cuff pressure is that the tube is too small in diameter, resulting in overfilling of the cuff to achieve a seal in the trachea. If the volume of air in the cuff needed to achieve a seal exceeds the nominal volume of the cuff, this suggests that the tube diameter is too small. The nominal cuff volume is the volume below which the cuff pressure is $<$ 25 mm Hg ex vivo. Another common cause of high cuff pressure is malposition of the tube (eg, cuff inflated in the stoma). Other causes of high cuff pressure include overfilling of the cuff, tracheal dilation, and use of a low-volume high-pressure cuff. A cuff management algorithm is shown in Figure 15.[18]

The tight-to-shaft cuff minimizes airflow obstruction around the outside of the tube when the cuff is deflated. It is a high-pressure low-volume cuff intended for patients requiring intermittent cuff inflation. When the cuff is deflated, speech and use of the upper airway is facilitated. The cuff is constructed of a silicone material. It should be inflated with sterile water because the cuff will automatically deflate over time in-situ due to gas permeability.

Table 3. Dimensions of Several Commercially Available Extra Length Tracheostomy Tubes

Inner Diameter (mm)	Outer Diameter (mm)	Length (mm)
Portex Extra Horizontal Length Blue Line Tracheostomy Tubes		
7.0	9.7	84 (horizontal length 18)
8.0	11.0	95 (horizontal length 22)
9.0	12.4	106 (horizontal length 28)
Portex Double Cuff Blue Line Tracheostomy Tubes (Extra Vertical Length)		
7.0	9.7	83 (vertical length 41)
8.0	11.0	93 (vertical length 45)
9.0	12.4	103 (vertical length 48)
10.0	13.8	113 (vertical length 52)
Shiley TracheoSoft XLT Proximal Extension Tracheostomy Tubes		
5.0	9.6	90 (20 proximal, 37 radial, 33 distal)
6.0	11.0	95 (23 proximal, 38 radial, 34 distal)
7.0	12.3	100 (27 proximal, 39 radial, 34 distal)
8.0	13.3	105 (30 proximal, 40 radial, 35 distal)
Shiley TracheoSoft XLT Distal Extension Tracheostomy Tubes		
5.0	9.6	90 (5 proximal, 37 radial, 48 distal)
6.0	11.0	95 (8 proximal, 38 radial, 49 distal)
7.0	12.3	100 (12 proximal, 39 radial, 49 distal)
8.0	13.3	105 (15 proximal, 40 radial, 50 distal)

Fig. 9. Flexible tracheostomy tubes with adjustable flange. Hv = high-volume. LP = low-pressure.

Table 4. Dimensions of Flexible Tracheostomy Tubes With an Adjustable Flange

Inside Diameter (mm)	Outside Diameter (mm)	Length (mm)
Rusch Ulr TracheoFlex With Adjustable Flange		
7.0	10.8	82
8.0	11.7	107
9.0	12.7	137
10.0	13.7	137
11.0	14.2	137
Bivona Mid-Range Adjustable Neck Flange		
6.0	8.7	110
7.0	10.0	120
8.0	11.0	130
9.0	12.3	140

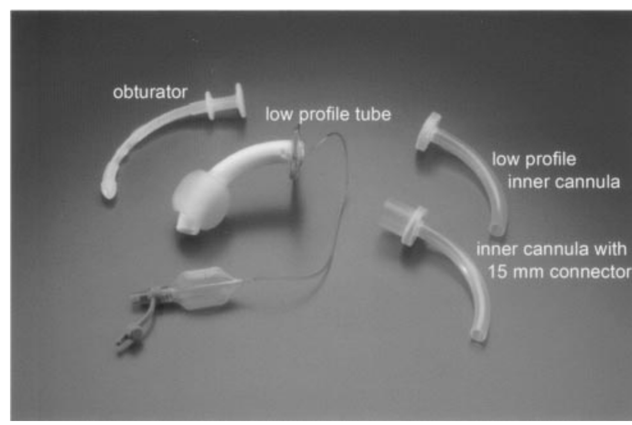


Fig. 10. Low-profile tracheostomy tube. (Courtesy of Smiths Medical, Keene, New Hampshire.)

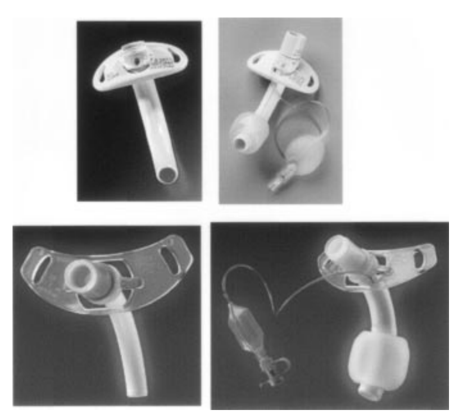


Fig. 11. Uncuffed and cuffed tracheostomy tubes. (Courtesy of Smiths Medical, Keene, New Hampshire and Tyco Healthcare, Pleasanton, California.)

A foam cuff consists of a large-diameter high-residual-volume cuff composed of polyurethane foam covered by a silicone sheath (Fig. 16).[19,20] The concept of the foam cuff was designed to address the issues of high lateral tracheal-wall pressures that lead to complications such as tracheal necrosis and stenosis. Before insertion, air in the cuff is evacuated by a syringe attached to the pilot port. Once the tube is in place, the syringe is removed to allow the cuff to

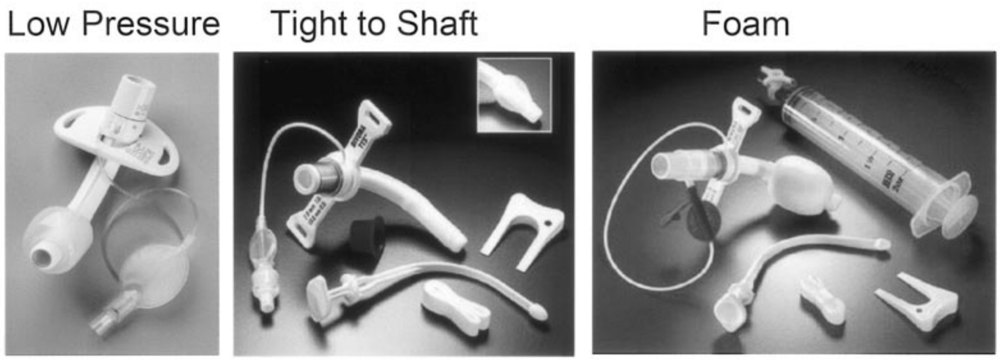


Fig. 12. Examples of low-pressure, tight-to-shaft, and foam-filled tracheostomy tube cuffs.

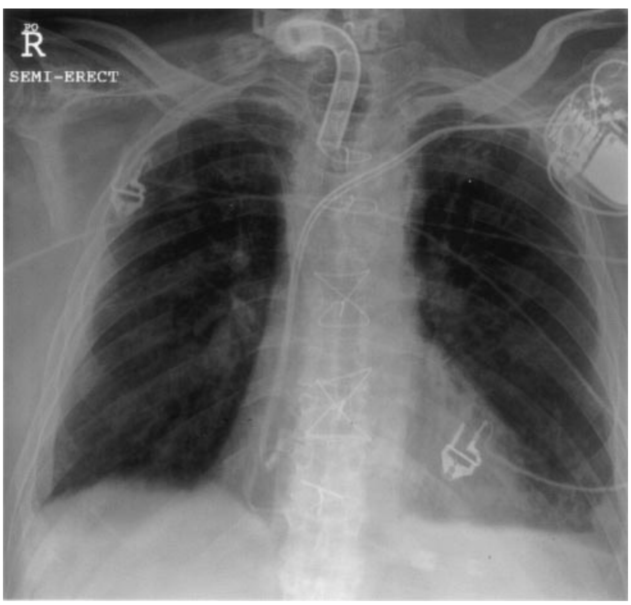


Fig. 13. Anterior-posterior chest radiograph of a patient with substantial tracheal dilation at the site of the tracheostomy tube cuff.

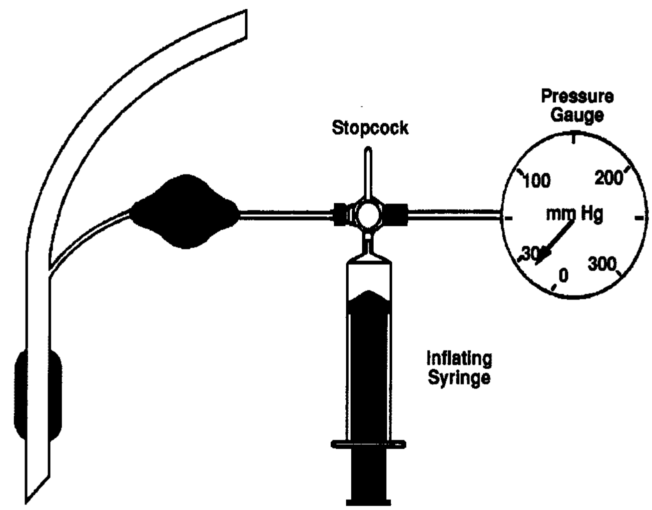


Fig. 14. Diagram of the equipment used to measure cuff pressure.

re-expand against the tracheal wall. The pilot tube remains open to the atmosphere, so the intra-cuff pressure is at ambient levels. The open pilot port also permits compression and expansion of the cuff during the ventilatory cycle. The degree of expansion of the foam is a determining factor of the degree of tracheal-wall pressure. As the foam further expands, lateral tracheal-wall pressure increases. When used properly, this pressure does not exceed 20 mm Hg. The proper size is important to maintain a seal and the benefit from the pressure-limiting advantages of the foam-filled cuff. If the tube is too small, the foam will inflate to its unrestricted size, causing loss of ventilation and loss of protection against aspiration. If a leak occurs during positive-pressure ventilation with the foam cuff, it can be attached to the ventilator circuit so that cuff pressure approximates airway pressure. If the tube is too large, the foam is unable to expand properly to provide the desired cushion, with increased pressure against the tracheal wall. The manufacturer recommends periodic cuff deflation to determine the integrity of the cuff and to prevent the silicone cuff from adhering to the tracheal mucosa. Despite the long availability of this cuff type, it is not commonly used. Its use is often reserved for patients who have already developed tracheal injury related to the cuff.

Changing the Tracheostomy Tube

Occasionally a tracheostomy tube must be changed (eg, if the cuff is ruptured or if a different style of tube is needed). The need for routine tracheostomy tube changes is unclear. In an observational study, Yaremchuk[21] reported fewer complications due to granulation tissue after implementation of a policy in which tracheostomy tubes were changed every 2 weeks.

Changing the tracheostomy tube is usually straightforward once the stoma is well formed, which may require 7–10 days after the tracheostomy is first placed. If the tube must be changed before the stoma is well formed, it is

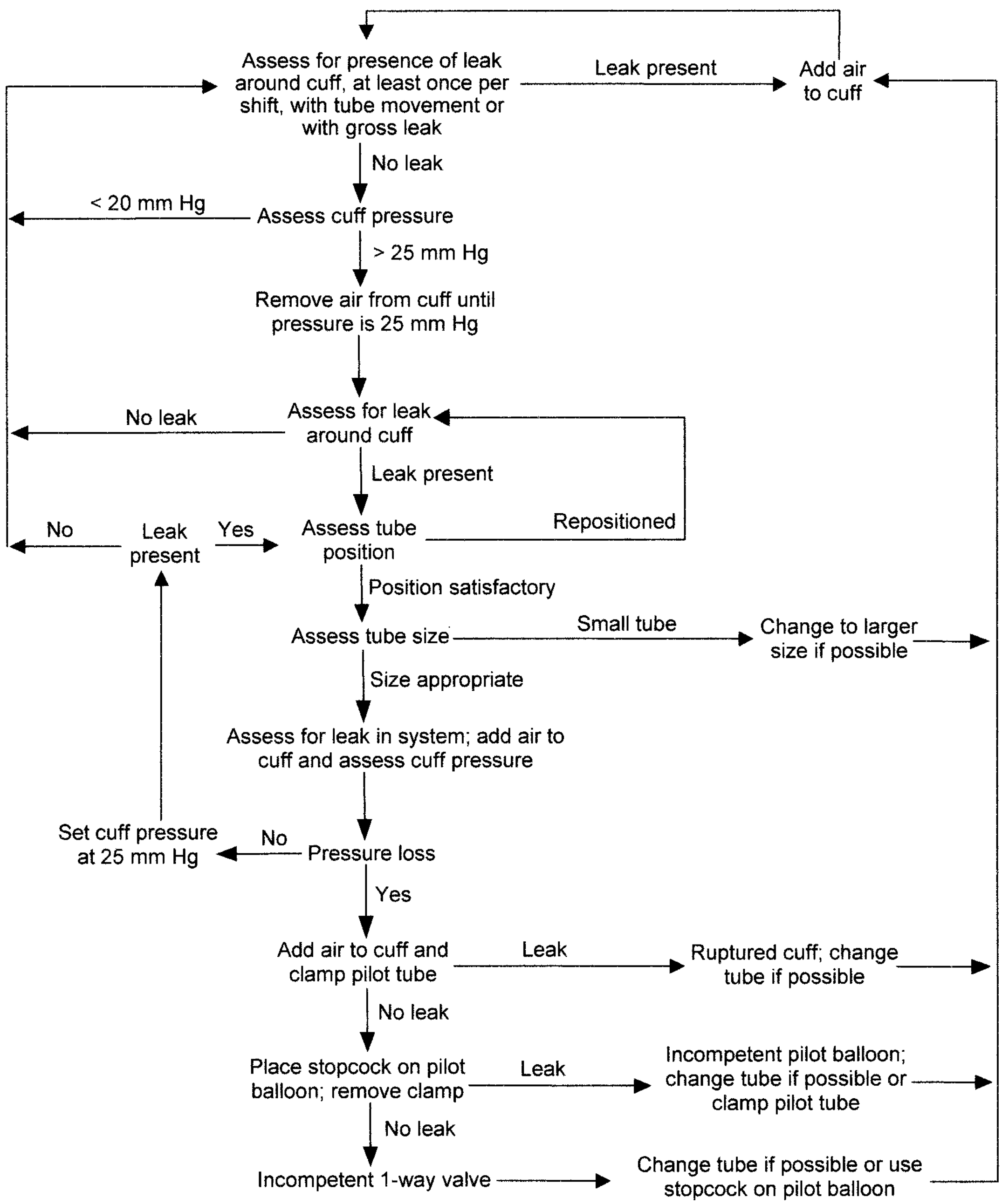


Fig. 15. Algorithm to address issues with an artificial airway cuff leak. (From Reference 18.)

advisable that the physician who performed the initial placement perform the tracheostomy tube change. In these cases it is also important that an individual skilled in endotracheal intubation is available in the event that the tracheostomy tube cannot be replaced. Generally, it is easier to replace the tube with one that has a smaller OD.

The new tracheostomy tube can usually be inserted using the obturator packaged with the tube. If difficulty is anticipated during a tracheostomy tube change, a tube changer can be used to facilitate this procedure. The tube changer is passed through the tube into the trachea. The tube is then withdrawn while keeping the tube changer in place and the new tube is then passed over the tube changer into the trachea.

Fenestrated Tracheostomy Tubes

The fenestrated tracheostomy tube is similar in construction to standard tracheostomy tubes, with the addition of an opening in the posterior portion of the tube above the cuff (Fig. 17). In addition to the tracheostomy tube with a

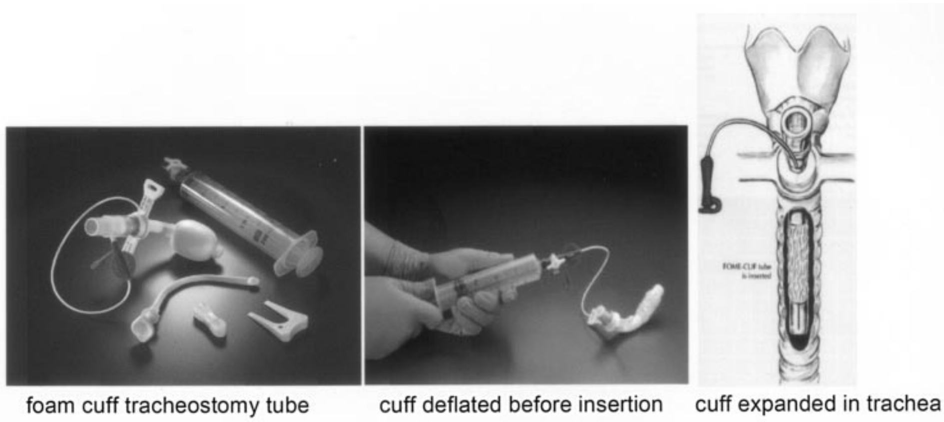


Fig. 16. Foam cuff design. (Courtesy of Smiths Medical, Keene, New Hampshire.)

Fig. 17. Fenestrated tracheostomy tubes. Note the 2 styles of fenestration.

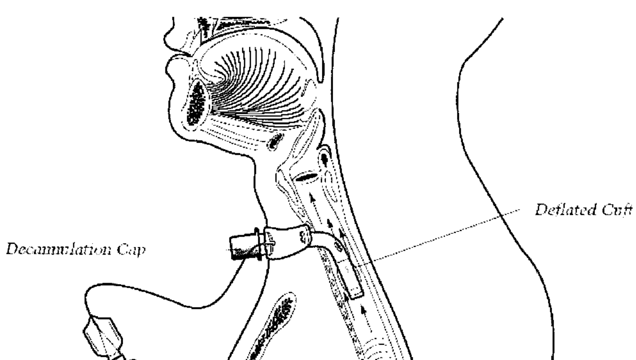


Fig. 18. With fenestrated tracheostomy tube and cuff deflation, the patient can breathe through the upper airway. (Courtesy of Smiths Medical, Keene, New Hampshire.)

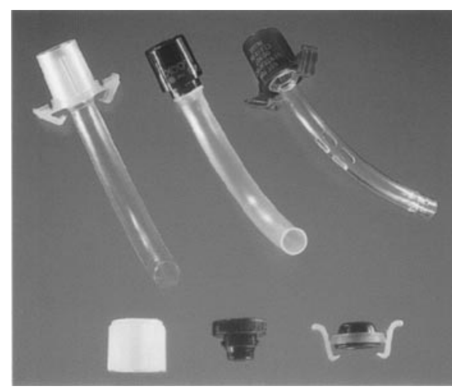


Fig. 19. Examples of decannulation caps (below) and associated inner cannulae (above). (Courtesy of Tyco Healthcare, Pleasanton, California.)

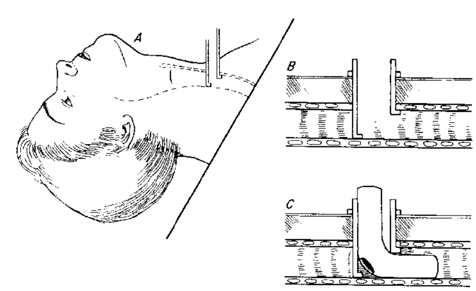


Fig. 20. Measurement for fenestration. A: Hyperextend head for good visualization. B: Bedside measurements with sterile pipe cleaners, anterior and posterior wall-to-skin measurement. C. Measurements determine location of fenestration on tracheostomy tube. (From Reference 1, with permission.)

fenestration, a removable inner cannula and a plastic plug are supplied. With the inner cannula removed, the cuff deflated, and the normal air passage occluded, the patient can inhale and exhale through the fenestration and around the tube (Fig. 18). This allows for assessment of the patient's ability to breathe through the normal oral/nasal route (preparing the patient for decannulation) and permits air to pass by the vocal cords (allowing phonation). Supplemental oxygen administration to the upper airway (eg, nasal cannula) may be necessary if the tube is capped. The cuff must be completely deflated by evacuating all of the air before the tube is capped. The decannulation cap (Fig. 19) is then put in place to allow the patient to breathe through the fenestrations and around the tube.

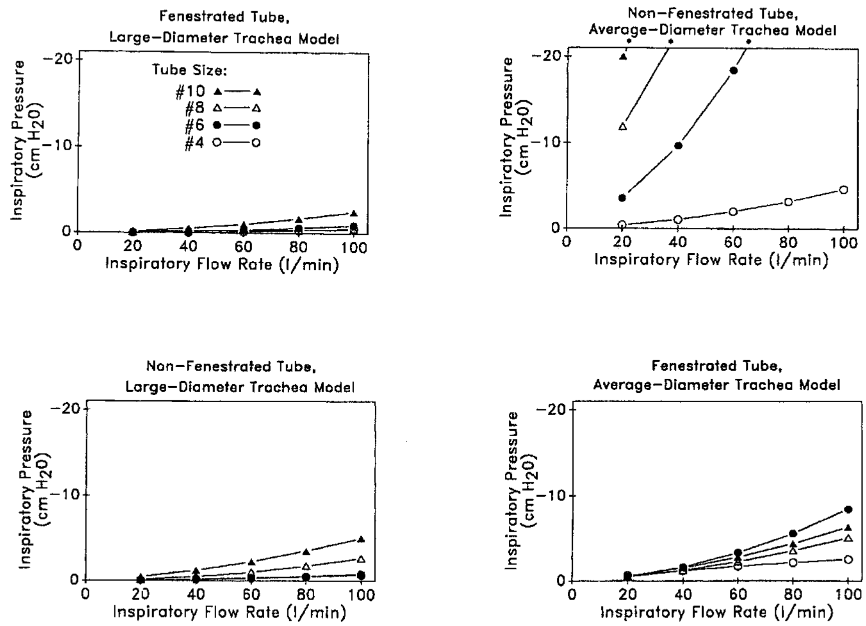


Fig. 21. Inspiratory pressures required to generate flows with fenestrated and nonfenestrated tracheostomy tubes. (From Reference 23, with permission.)

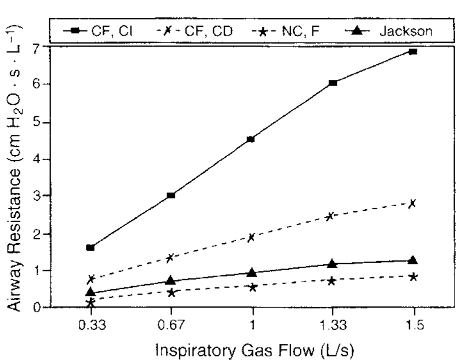


Fig. 22. Airway resistance during tracheostomy-tube occlusion. CF, CI = cuffed fenestrated, cuff inflated. CF, CD = cuffed fenestrated, cuff deflated. NC, F = uncuffed fenestrated. (From Reference 24, with permission.)

Table 5. Comparison in Tube Dimensions for Shiley Single-Cannula Tube and Dual-Cannula Tube*

Shiley SCT		Size	Shiley DCT	
Inner Diameter (mm)	Outer Diameter (mm)		Inner Diameter (mm)	Outer Diameter (mm)
6.0	8.3	6	6.4 (8.1 without IC)	10.8
8.0	10.9	8	7.6 (9.1 without IC)	12.2
10.0	13.3	10	8.9 (10.7 without IC)	13.8

*Note: Inner diameter of outer cannula is for narrowest portion of the shaft.
SCT = single-cannula tube
DCT = dual-cannula tube
IC = inner cannula

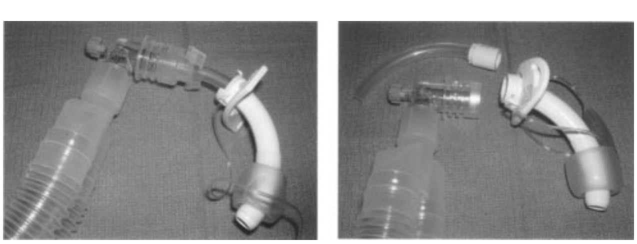


Fig. 23. An example of an inner cannula in which the 15-mm ventilator attachment is connected to the inner cannula. If the inner cannula is removed, it is not possible to attach the ventilator.

Unfortunately fenestrated tracheostomy tubes often fit poorly. The standard commercially available tubes can substantially increase flow resistance through the upper airway if the fenestrations are not properly positioned. The risk of this complication may be decreased if a tube with several fenestrations rather than a single fenestration is used. Techniques have been described to assure proper placement of the fenestrations within the airway (Fig. 20). Moreover, custom-fenestrated tubes can be ordered from several manufacturers. Even with these measures, the fenestrations may become obstructed by the formation of granulation tissue, resulting in airway compromise.[22] Proper position of the fenestrations in the airway should be inspected regularly.

Hussey and Bishop[23] reported that the effort required for gas flow across the native airway in the absence of a fenestration can be substantial (Fig. 21). Beard and Monaco[24] reported that the presence of a cuff, either inflated or deflated, can increase the amount of ventilatory work required of the patient (Fig. 22). They recommended that

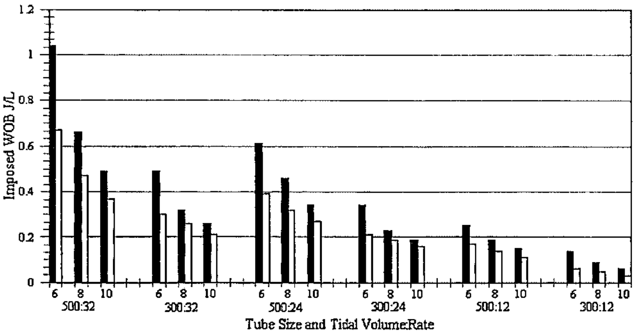


Fig. 24. Imposed work of breathing (WOB) for Shiley size 6, 8, and 10 tracheostomy tubes, with tidal volumes of 500 and 300 mL and respiratory rates of 12, 24, and 32 breaths/min. Black bars denote WOB with the cannula in place. Open bars denote WOB with the cannula removed. (From Reference 26, with permission.)

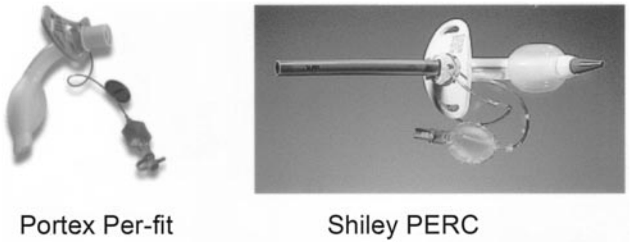


Fig. 25. Portex and Shiley percutaneous tracheostomy tubes. (Courtesy of Smiths Medical, Keene, New Hampshire and Tyco Healthcare, Pleasanton, California.)

Table 6. Dimensions of Tracheostomy Tubes Designed Specifically to Be Inserted Using Percutaneous Technique

Tube	Inner Diameter (mm)	Outer Diameter (mm)	Length (mm)
Portex Per-fit 7	7.0 (6.0 with IC)	9.6	82.0
Portex Per-fit 8	8.0 (7.0 with IC)	10.9	86.0
Portex Per-fit 9	9.0 (8.0 with IC)	12.3	93.0
Shiley 6 PERC	6.4	10.8	74
Shiley 8 PERC	7.6	12.2	79

IC = inner cannula

uncuffed tubes should be used to decrease patient work of breathing when the tube is capped, to improve patient comfort during the process of decannulation. If the cuff is deflated or an uncuffed tube is used, the patient must be observed carefully for potential aspiration of upper-airway secretions or oral fluids. Upper-airway reflexes should be carefully assessed before attempts at cuff deflation and decannulation.

Dual-Cannula Tracheostomy Tubes

Some tracheostomy tubes are designed to be used with an inner cannula, and these are called dual-cannula

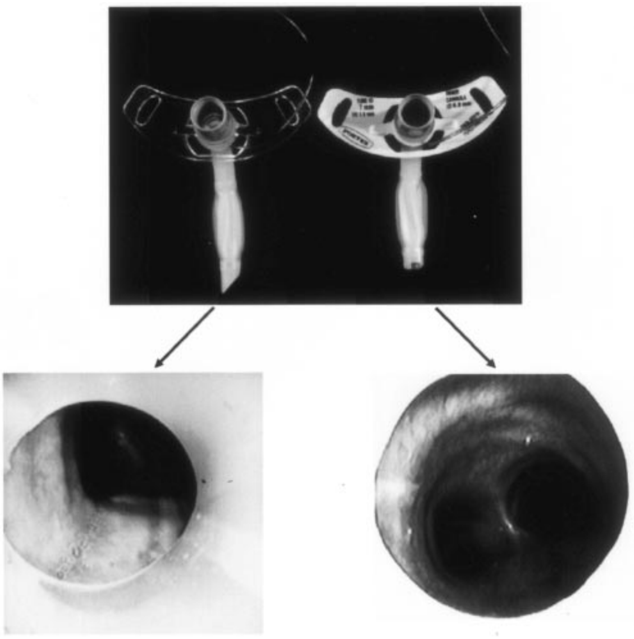


Fig. 26. Standard (top left) and modified (top right) Portex Per-fit percutaneous tracheostomy tubes. Bronchoscopic views of the distal tracheostomy tube opening from the standard (bottom left) and modified (bottom right) tracheostomy tubes. (From Reference 27, with permission.)

tracheostomy tubes. In some cases, the 15-mm attachment is on the inner cannula, and a ventilator cannot be attached unless the inner cannula is in place (Fig. 23). The inner cannula can be disposable or reusable. The use of an inner cannula allows it to be cleaned or replaced at regular intervals. It has been hypothesized that this may reduce biofilm formation and the incidence of ventilator-associated pneumonia. However, data are lacking to support this hypothesis, and the results of one study suggested that changing the inner cannula on a regular basis in the critical care unit is unnecessary.[25] The inner cannula can be removed to restore a patent airway if the tube occludes, which may be an advantage for long-term use outside an acute care facility. If a fenestrated tracheostomy tube is used, the inner cannula occludes the fenestrations unless there are also fenestrations on the inner cannula.

One potential issue with the use of an inner cannula is that it reduces the ID of the tracheostomy tube (Table 5) and thus the imposed work of breathing for a spontaneously breathing patient is increased. This was investigated by Cowan et al[26] in an in vitro study, in which they reported a significant decrease in imposed work of breathing when the inner cannula was removed (Fig. 24). They concluded that increasing the ID of the tracheostomy tube by removing the inner cannula may be beneficial in spontaneously breathing patients.

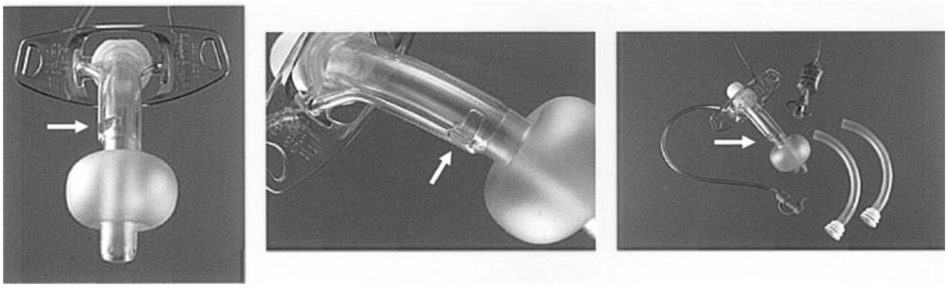


Fig. 27. Portex Blue Line Ultra Suctionaid tracheostomy tube. The arrow indicates the position of the suction port above the cuff. (Courtesy of Smiths Medical, Keene, New Hampshire.)

Table 7. Dimensions of Portex Blue Line Ultra Suctionaide Tracheostomy Tube Designed for Subglottic Suction

Inner Diameter (mm)	Outer Diameter (mm)	Length (mm)
6.0	9.2	64.5
7.0	10.5	70.0
7.5	11.3	73.0
8.0	11.9	75.5
8.5	12.6	78.0
9.0	13.3	81.0

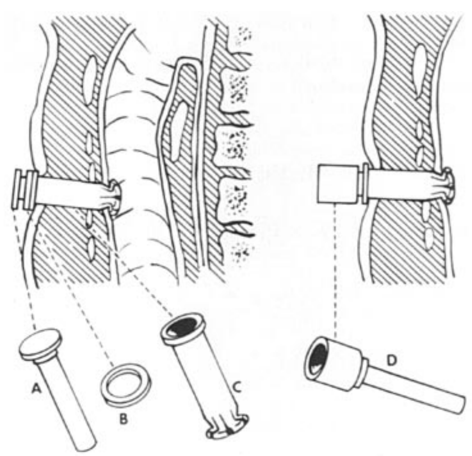


Fig. 28. Olympic tracheostomy button (Olympic Medical, Seattle, Washington) positioned against the anterior tracheal wall. The tube is occluded with a solid plug (A) and fitted exactly to length with spacing washers (B). On the right is shown the distal flower-petal flanges (C) that expand to fit the tube into the trachea without sutures or ties. A positive-pressure adapter (D) can be attached to allow assisted ventilation. (From Reference 3, with permission.)

Percutaneous Tracheostomy Tubes

Several tracheostomy tubes are designed specifically for insertion as part of the percutaneous dilatational tracheostomy procedure (Fig. 25 and Table 6). The Portex Per-fit flexible tube features a tapered distal tip and a low-profile cuff designed to reduce insertion force and more readily conform to the patient's anatomy. Although the design of the cuff makes insertion of the tube easier, the cuff characteristics resemble those of a low-volume high-pressure cuff rather than a low-pressure high-volume cuff. The Shiley PERC tracheostomy tube has a tapered distal tip and inverted cuff shoulder for easier insertion. It is designed specifically to be used with the Cook Percutaneous Tracheostomy Introducer Set. This cuff provides a low-pressure seal.

Trottier et al[27] reported that 57% of patients with a Portex Per-Fit tracheostomy tube placed percutaneously had a $\geq$ 25% obstruction of the tracheostomy tube, and $\geq$ 40% obstruction was visualized in 41% of the patients (Fig. 26). The cause of the partial tracheostomy-tube obstruction was the membranous posterior tracheal wall encroaching on the tracheostomy tube lumen. Several patients displayed a dynamic component to the obstruction, such that when the patient's intrathoracic pressure increased, the degree of obstruction also increased. One patient displayed clinical signs and symptoms of tracheostomy-tube obstruction. This patient was obese and had a large neck, such that the tracheostomy tube was too short for the patient. These findings prompted the investigators to recommend modifications to the tube to lessen the degree of partial tracheostomy-tube obstruction. The standard tracheostomy tube was modified to include a shortened posterior bevel (the longest portion of the tracheostomy tube posteriorly) and a decreased length and angle of the tracheostomy tube. Following this modification, $\geq$ 25% tube obstruction was observed in only 1 of 17 patients.

Subglottic Suction Port

Endotracheal tubes have been available for some time with a port above the cuff to facilitate aspiration of subglottic secretions, minimize their aspiration past the cuff, and thus decrease the risk of ventilator-associated pneumonia. Subglottic secretion drainage is associated with decreased incidence of ventilator-associated pneumonia,

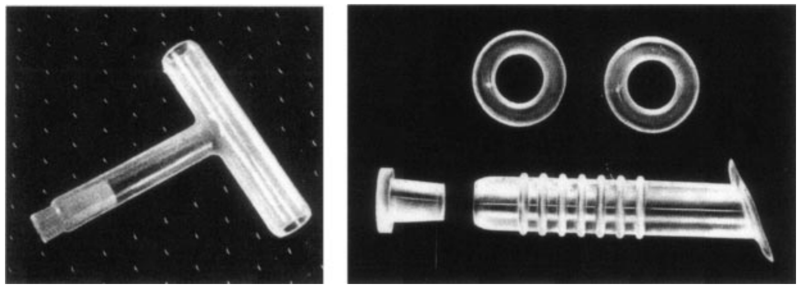


Fig. 29. Montgomery T-tube (left) and Montgomery silicone tracheal cannula (right). (From Reference 1, with permission.)

especially early-onset pneumonia.[28–33] Based on this evidence, it has been recommended that clinicians consider the use of subglottic secretion drainage.[34] A tracheostomy tube capable of subglottic suction has recently become available (Fig. 27). To date, there has been no report of the effectiveness of this tube. One consideration in its use is that a larger OD of the tube is necessary to facilitate the suction port (Table 7).

Stoma Maintenance Devices

Several approaches can be used for stomal maintenance in patients who cannot be decannulated. One of the easiest approaches is to use a small cuffless tracheostomy tube (eg, 4 cuffless). Another approach is to use a tracheostomy button (Fig. 28).[32] These appliances are generally made of Teflon and consist of a hollow outer cannula and an inner solid cannula. This device fits from the skin to just inside the anterior wall of the trachea. With the solid inner cannula in place, the patient breathes through the upper airway. When the inner cannula is removed, the patient can breathe through the button, and a suction catheter can be passed through the button to aid airway clearance. Since a tracheostomy button does not have a cuff, its use is limited when there is a risk of aspiration or during positive-pressure ventilation. Other devices used for stomal maintenance include the Montgomery T-tube and the Montgomery silicone tracheal cannula (Fig. 29).

Mini-Tracheostomy Tubes

The mini-tracheostomy tube is a small bore cannula (4.0 mm ID) inserted into the trachea through the cricothyroid membrane or the tracheal stoma after decannulation. It can be used for oxygen administration. However, it is used primarily for patients with airway clearance issues[35] because it allows bronchial lavage and suctioning with a 10 French suction. It is uncuffed and generally unsuitable for provision of positive pressure ventilation.

Summary

Tracheostomy tubes are available in a variety of sizes and styles. It is important for respiratory therapists and physicians caring for patients with tracheostomy tubes to understand these differences and select a tube that appropriately fits the patient.

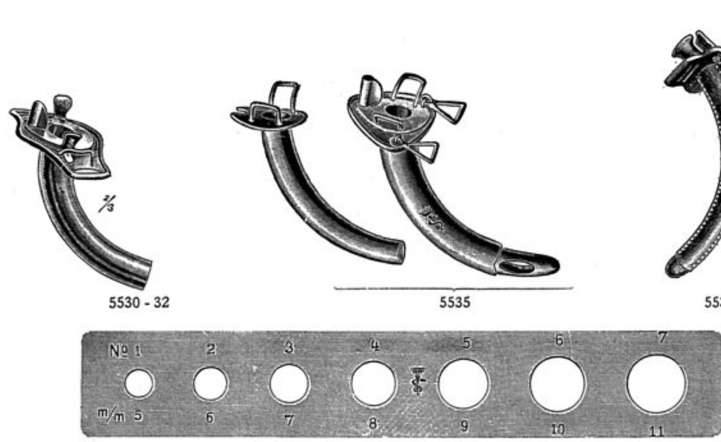
ACKNOWLEDGMENT

I wish to thank the staff of the Respiratory Acute Care Unit (RACU) who have taught me that selection of the correct tracheostomy tube makes a difference.

REFERENCES

1. Wilson DJ. Airway appliances and management. In: Kacmarek RM, Stoller JK. Current respiratory care. Philadelphia: PC Decker; 1988.
2. Wilson DJ. Airway management of the ventilator-assisted individual. Probl in Respir Care 1988;1(2):192–203.
3. Godwin JE, Heffner JE. Special critical care considerations in tracheostomy management. Clin Chest Med 1991;12(3):573–583.
4. Mullins JB, Templer JW, Kong J, Davis WE, Hinson J. Airway resistance and work of breathing in tracheostomy tubes. Laryngoscope 1993;103(12):1367–1372.
5. Rumbak MJ, Walsh FW, Anderson WM, Rolfe MW, Solomon DA. Significant tracheal obstruction causing failure to wean in patients requiring prolonged mechanical ventilation: a forgotten complication of long-term mechanical ventilation. Chest 1999;115(4):1092–1095.
6. Bach JR, Alba AS. Tracheostomy ventilation: a study of efficacy with deflated cuffs and cuffless tubes. Chest 1990;97(3):679–683.
7. Cooper JD, Grillo HC. The evolution of tracheal injury due to ventilatory assistance through cuffed tubes: a pathologic study. Ann Surg 1969;169(3):334–348.
8. Cooper JD, Grillo HC. Experimental production and prevention of injury due to cuffed tracheal tubes. Surg Gyn Obs 1969;129(6): 1235–1241.
9. Cooper JD, Grillo HC. Analysis of problems related to cuffs on intratracheal tubes. Chest 1972;62(2):21S–27S.
10. Knowlson GT, Bassett HF. The pressures exerted on the trachea by endotracheal inflatable cuffs. Br J Anaesth 1970;42(10):834–837.
11. Dobrin P, Canfield T. Cuffed endotracheal tubes: mucosal and tracheal wall blood flow. Am J Surg 1977;133(5):562–568.
12. Bernhard WN, Yost L, Joynes D, Cothalis S, Turndorf H. Intracuff pressures in endotracheal and tracheostomy tubes: related cuff physical characteristics. Chest 1985;87(6):720–725.
13. Dunn CR, Dunn DL, Moser KM. Determinants of tracheal injury by cuffed tracheostomy tubes. Chest 1974;65(2):128–135.
14. Seegobin RD, van Hasselt GL. Endotracheal cuff pressure and tracheal mucosal blood flow: endoscopic study of effects of four large volume cuffs. BMJ 1984;288(6422):965–968.

15. Honeybourne D, Costello JC, Barham C. Tracheal damage after endotracheal intubation: comparison of two types of endotracheal tubes. Thorax 1982;37(7):500–502.
16. Pavlin EG, Van Mimwegan D, Hornbein TF. Failure of a high-compliance low-pressure cuff to prevent aspiration. Anesthesiology 1975;42(2):216–219.
17. Bernhard WN, Cottrell JE, Sivakumaran C, Patel K, Yost L, Turndorf H. Adjustment of intracuff pressure to prevent aspiration. Anesthesiology 1979;50(4):363–366.
18. Hess DR. Managing the artificial airway. Respir Care 1999;44(7): 759–772.
19. Kamen JM, Wilkinson CJ. A new low-pressure cuff for endotracheal tubes. Anesthesiology 1971;34(5):482.
20. King K, Mandava B, Kamen JM. Tracheal tube cuffs and tracheal dilatation. Chest 1975;67(4):458–462.
21. Yaremchuk K. Regular tracheostomy tube changes to prevent formation of granulation tissue. Laryngoscope 2003;113(1):1–10.
22. Siddharth P, Mazzarella L. Granuloma associated with fenestrated tracheostomy tubes. Am J Surg 1985;150(2):279–180.
23. Hussey JD, Bishop MJ. Pressures required to move gas through the native airway in the presence of a fenestrated vs a nonfenestrated tracheostomy tube. Chest 1996;110(2):494–497.
24. Beard B, Monaco MJ. Tracheostomy discontinuation: impact of tube selection on resistance during tube occlusion. Respir Care 1993; 38(3):267–270.
25. Burns SM, Spilman S, Wilmoth D, Carpender R, Turrentine B, Wiley B, et al. Are frequent inner cannula changes necessary? A pilot study. Heart Lung 1998;27(1):58–62.
26. Cowan T, Op't Holt TB, Gegenheimer C, Izenberg S, Kulkarni P. Effect of inner cannula removal on the work of breathing imposed by tracheostomy tubes: a bench study. Respir Care 2001;46(5):460–465.
27. Trottier SJ, Ritter S, Lakshmanan R, Sakabu SA, Troop BR. Percutaneous tracheostomy tube obstruction: warning. Chest 2002;122(4): 1377–1381.
28. Valles J, Artigas A, Rello J, Bonsoms N, Fontanals D, Blanch L, et al. Continuous aspiration of subglottic secretions in preventing ventilator-associated pneumonia. Ann Intern Med 1995;122(3):179–186.
29. Metz C, Linde HJ, Gobel L, Gobel F, Taeger K. Influence of intermittent subglottic lavage on subglottic colonisation and ventilator-associated pneumonia. Clin Intensive Care 1998;9:20–24.
30. Mahul P, Auboyer C, Jospe R, Ros A, Guerin C, el Khouri Z, et al. Prevention of nosocomial pneumonia in intubated patients: respective role of mechanical subglottic secretions drainage and stress ulcer prophylaxis. Intensive Care Med 1992;18(1):20–25.
31. Kollef MH, Skubas NJ, Sundt TM. A randomized clinical trial of continuous aspiration of subglottic secretions in cardiac surgery patients. Chest 1999;116(5):1339–1346.
32. Smulders K, van der Hoeven H, Weers-Pothoff I, Vandenbroucke-Grauls C. A randomized clinical trial of intermittent subglottic secretion drainage in patients receiving mechanical ventilation. Chest 2002;121(3):858–862.
33. Dodek P, Keenan S, Cook D, Heyland D, Jacka M, Hand L, et al. Evidence-based clinical practice guideline for the prevention of ventilator-associated pneumonia. Ann Intern Med 2004;141(4): 305–313.
34. Long J, West G. Evaluation of the Olympic trach button as a precursor to tracheostomy tube removal (abstract). Respir Care 1980; 25(12):1242–1243.
35. Bonde P, Papachristos I, McCraith A, Kelly B, Wilson C, McGuigan JA, McManus K. Sputum retention after lung operation: prospective, randomized trial shows superiority of prophylactic minitracheostomy in high-risk patients. Ann Thorac Surg 2002;74(1):196–202; discussion 202–203.



Scale for Trachea Tubes 5530 to 5538

Tracheostomy tubes, obturators, and sizing scale.
Catalogue of Surgical Instruments of Superior Quality, 24th edition.
Seattle Washington: Biddle & Crowther Inc, 1935.
Courtesy Health Sciences Libraries, University of Washington